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A DETERMINATION OF THE WIDEBAND MODULATION CAPABILITIES OF JAMMING TRANSMITTER AN/ALT-2

[UNCLASSIFIED TITLE]

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December 30, 1960

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Washington, D.C.

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ABSTRACT
[Confidential]

In the interest of developing improved jamming effectiveness in the current modifications to the AN/ALT-2 transmitter portion of the AN/ALQ-23 automatic search and jam system, an analysis was made of the modulation capabilities of its X-band unit. Test data supplied by Litton Industries and Bomac, Inc., makers of the component magnetrons, indicated that noise modulation components out to 10 Mc could not be reproduced in the X-band magnetron output under present equipment limitations. It now appears that the manufacturers' test data were affected by certain modifying conditions, since studies at this Laboratory indicate no inherent limitations within the tubes to prevent reproduction of video modulation components up to at least 10 Mc.

PROBLEM STATUS

This report covers interim services under the authorized problems.

AUTHORIZATION

NRL Problems R06-12 and R06-09
BuWeps Projects EL-9A-0334
and RAV 33 R001/5661/F010-02-002
BuShips Projects S-F010-02-01, Task 9298 and SS301-001

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A DETERMINATION OF THE WIDEBAND MODULATION CAPABILITIES OF JAMMING TRANSMITTER AN/ALT-2
[Unclassified Title]

INTRODUCTION

In every cw noise jammer to come under the scrutiny of this Laboratory, the one recurring deficiency, without a single exception, has been in the modulation process. It is becoming increasingly evident that techniques for generating and applying large amplitudes of broadband, random noise modulation are not generally understood. Instrumentation for measuring and analyzing such spectra has, until very recently, been unavailable outside of this Laboratory. This latter factor appears to be most critical in the consistent failure of ECM designers to produce jamming transmitters with acceptable and predictable noise modulation characteristics, since, in the development phase, they generally rely on the use of periodic waveforms, neglecting the transient conditions under which video circuitry must operate with random noise. The result has been a number of complex jamming systems capable of rapid signal intercept, signal analysis, and transmitter set-on but which, in their fundamental function as jammers, have all been found deficient.

The Navy procurement bureaus have become increasingly concerned with these problems and frequently request this Laboratory to comment on ECM equipment specifications, to make preliminary analyses of systems prior to operational evaluation, and to discuss with system contractors the fundamentals of design and measurement peculiar to the development of effective random noise jamming systems.

PROBLEM BACKGROUND

In view of the serious shortcomings in noise jamming transmitters, the Navy materiel bureaus have established more definitive specifications regarding the modulation characteristics of the AN/ALQ-23 automatic search and jam systems now under procurement. The AN/ALQ-23 comprises a mechanically swept intercept and lock-on receiver in conjunction with an AN/ALT-2, a mechanically tuned, medium-power, noise-modulated magnetron transmitter. Although primarily an airborne jamming system, the AN/ALQ-23, with appropriate modifications, has also been adapted as an integral unit in the AN/SLQ-10 shipboard ECM system.

The present investigation is concerned with X-band portions of the AN/ALT-2 transmitter unit. In the prototype developed at this Laboratory, the X-band AN/ALT-2 had the capability of generating an rf output spectrum with random noise components extending continuously from 50 kc to 5.0 Mc. Requirements for higher frequency noise components have been established from numerous laboratory studies and operational evaluations and are accepted as essential for effective radar jamming. With the advent of narrowing radar pulses and correspondingly broad receiver passbands, specifically in tracking radars, the 5-Mc upper limit of noise frequency is considered less than marginal at X-band with 10 Mc now a more acceptable compromise between jamming effectiveness and design complexity.

A previous modulation analysis (1) of a current commercial X-band AN/ALT-2 demonstrated serious deficiencies in the important element of wideband modulation when it was observed that the video content was essentially nonexistent above 2 Mc (Fig. 1). It did, however, surpass every other jammer evaluated at this Laboratory.

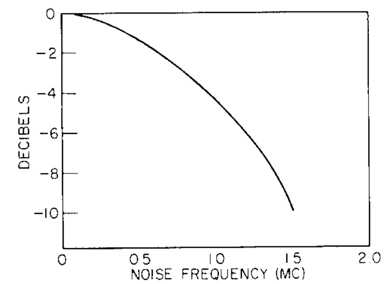


Fig. 1 - X-band video characteristics of a standard AN/ALT-2 with an internal modulator

TECHNICAL BACKGROUND

As a preliminary step in defining for the equipment manufacturer a fair and reasonable modulation specification, the two magnetron suppliers, Litton Industries and Bomac, Inc., were requested to determine the basic modulation characteristics of their respective tubes in order to establish any possible fundamental limitations. The results of these findings are included in Ref. 2, a technical proposal presented by Webcor, Inc., on their contracted modifications to the AN/ALQ-23. With the immediate interest limited to the X-band magnetrons the almost identical data supplied by each tube manufacturer is quoted as follows from Ref. 2:

> For the high-X-band magnetron that the amplitude modulation components of video frequency present in the magnetron rf output spectrum may extend from 50 kc/s to 10 Mc/s flat within 3.0 db when the modulating signal present at the magnetron input has the following voltage vs frequency characteristic:

Modulation Frequency (Mc)	Reference Voltage (db)
0.05	0
2.0	0
3.0	+1
5.0	+2
7.5	+6
10.0	+15

Based on these data, calculations by Webcor demonstrate that a series modulator tube with the 15-db dynamic capability, required to produce a flat rf output spectrum to 10 Mc, could not be accommodated in the present AN/ALT-2 configuration because of space and available power limitations.

From considerable experience with X-band magnetrons a certain skepticism toward these findings was maintained by NRL staff scientists, not regarding their accuracy but, rather, whether the conditions under which the measurements were taken permitted a true evaluation of the magnetron characteristics per se without, perhaps, reflecting incidental, unrecognized loading effects. It was recalled that the manufacturers, in evaluating the modulation requirements of their respective product, used as tube test vehicles standard noise jamming transmitters; if the transmitters were unmodified, factors other than basic

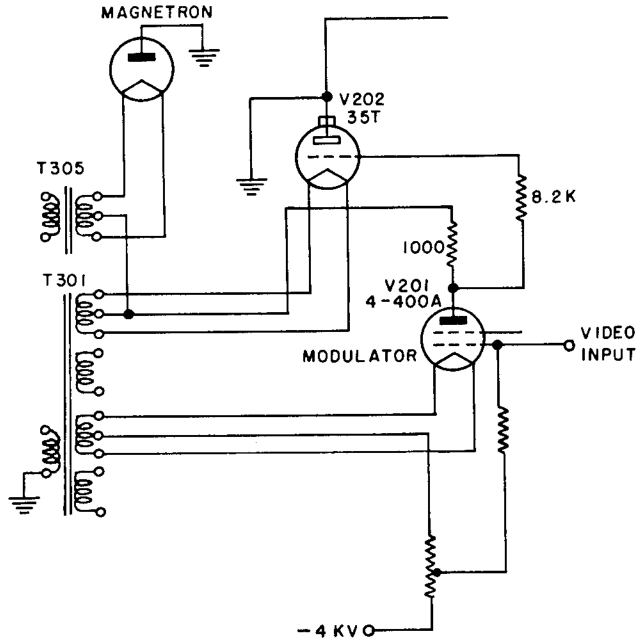


Fig. 2 - Standard AN/ALT-2 oscillator-modulator circuit (from Ref. 3)

magnetron characteristics could be present to affect the results. It was evident, however, that should the tube manufacturers' results be verified, the AN/ALT-2 specifications, delineating modulation requirements, must be adjusted to align them with what could be reasonably attained.

Analysis of the pertinent circuitry of the AN/ALT-2 as reproduced in Fig. 2 shows that the effective load into which the type 4-400A series modulator tube V201 must operate, aside from the dynamic impedance of the magnetron, is the sum of the capacities represented by the magnetron, the magnetron capacitance discharge tube V202, their respective filament transformers, and stray capacities.

As a preliminary, a measure of the capacity at the magnetron cathode (input) showed a value of 270 $\mu\mu$f, several times higher than anticipated. From its physical configuration the magnetron filament transformer T305 would be reasonably expected to have low secondary-to-primary capacity, say about 50 $\mu\mu$f, and assuming approximately 20 $\mu\mu$f for the magnetron input, the disparity between these and the measured total capacity must be in the circuitry of V202. It is significant to note in Fig. 2 that the filament winding for this tube is one of four secondary windings of T301, an encased, sealed transformer, which reasonably makes it suspect since such construction is not generally compatible with low-interwinding-capacity techniques.

V202 and pertinent circuitry are part of the transmitter look-through feature required in automatic operation, but since this investigation could be made under manual transmitter operation all extraneous circuitry and components could be deleted, resulting in a simple series circuit of the modulator tube and magnetron as shown in Fig. 3. Under this condition a remeasurement of capacity at the magnetron cathode now showed a more acceptable value of 56 $\mu\mu$f.

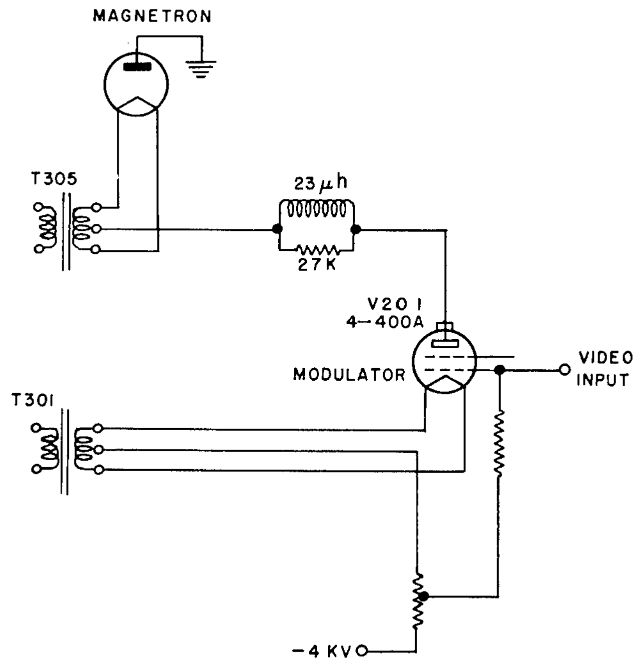


Fig. 3 - AN/ALT-2 oscillator-modulator circuit as modified for investigation

At this point there was strong evidence that the modulation characteristics offered by the tube manufacturers (2) inadvertently included extraneous factors and therefore were not truly representative of the magnetron per se. To further reinforce this evidence a fairly complete evaluation was undertaken.

MODULATION EVALUATION

Initially, an investigation of the original AN/ALT-2 modulation characteristics was considered advisable to verify the findings of the tube manufacturers. To accomplish this, the internal low-level modulator was uncoupled from the grid of V201 series modulator tube and replaced by an NRL-developed wide-band noise modulator, specifically designed for the X-band carcinotron jammer, NL/ALQ-F. With the degree of amplitude modulation set to 50%, video spectrum measurements were taken progressively through the transmitter circuit as indicated in Fig. 4. It will be observed from curve 1 that the input spectrum has a 4-db droop at about 9 Mc, rising at 9.7 Mc and dropping rapidly thereafter. As explained, the modulator was designed to operate into a load different from that presented by the 4-400A, and for this investigation no attempt was made to modify it for more favorable load matching. Curve 2 of Fig. 4 represents the spectrum appearing at the 4-400A plate. Since this point is several kilvolts above ground, an uncompensated RC network was used for these measurements, representing additional loading and possibly modifying the true spectrum to some extent. The final data represented by curve 3 (the detected rf output) is most significant; it shows the fall-off with increasing video frequency which could be predicted from the excessive capacity (270 μμf) appearing at the magnetron cathode of the original circuit. It should be noted that the effect of the loading was not as severe at the 4-400A plate (curve 2) since some degree of isolation is afforded by the 1-kilohm series resistor between modulator plate and magnetron cathode.

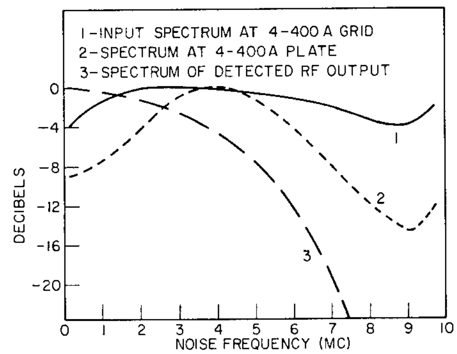


Fig. 4 - Video characteristics of a standard AN/ALT-2 (X-band) using an NRL wide-band noise driver

Analysis of Fig. 4 definitely justifies the data presented by the tube manufacturers but does not, as will be demonstrated, provide definitive information on the inherent modulation capabilities of the magnetron.

With the basic measurements completed on the unaltered equipment, the previously discussed circuit modifications shown in Fig. 3 were made. After some experimentation it was found that a very satisfactory overall response could be obtained by introduction of a single series peaking choke between modulator and magnetron to compensate for the high-frequency droop of the input spectrum. It is fully realized that this procedure may be an oversimplification from a practical system design point of view, but the thought must not be lost that the intent of this investigation is to establish basic modulation characteristics of the magnetron as a design parameter.

Under the modified circuit conditions, spectrum data were taken at several points as shown in Fig. 5. The effectiveness of the series compensation in holding up the higher frequencies is clearly demonstrated from curve 3 as compared to the input spectrum, curve 1.

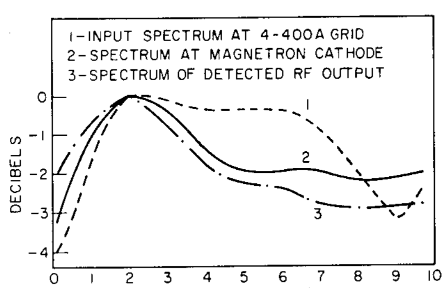


Fig. 5 - Video characteristics of a modified AN/ALT-2 (X-band) using an NRL wide-band noise driver

Of major significance, however, is a comparison of the video spectrum observed at the magnetron input with that derived from the detected rf output. The divergence of these results (curves 2 and 3) of less than 1.0 db conclusively demonstrates the ability of the magnetron to reproduce at the output with only minor degradation modulation components to at least 10 Mc introduced at the input.

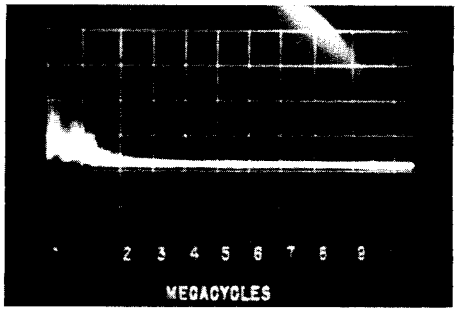


Fig. 6 - Output video spectrum of a standard AN/ALT-2 (X-band)

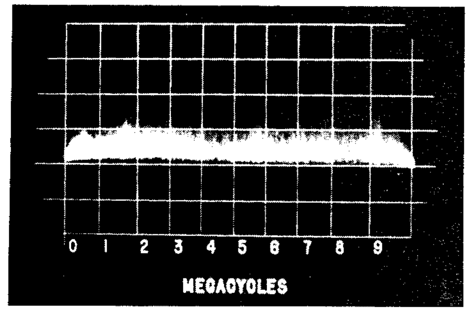


Fig. 7 - Output video spectrum of a modified AN/ALT-2 (X-band)

Figures 6 and 7 are included to portray the improvement in video response attained by the circuit revisions discussed. These photographs show the detected rf output of the original and the modified AN/ALT-2 respectively as displayed on an NRL video spectrum analyzer. In Fig. 7 the brightened areas in the vicinity of 2, 6, and 9 Mc are defects in the analyzer sweep and not spectral components.

An additional consideration in the video response of the magnetron is its dynamic impedance variation with operating frequency. As quoted in Ref. 2, from data supplied by the tube makers, this parameter varies between 330 ohms and 550 ohms over the range 8.8 kMc to 10.4 kMc. To evaluate the effect of this variation, video data were taken at the extremes and middle frequencies of the tuning range. From Fig. 8 it can be seen that the resultant plots show close agreement with about 1.0 db difference between the magnetron frequency limits.

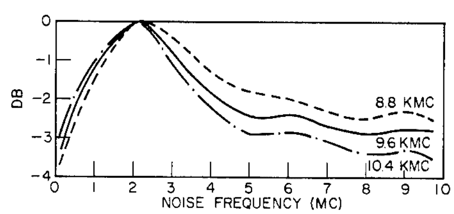


Fig. 8 - Detected noise output variation with carrier frequency of a modified AN/ALT-2 (X-band)

An analysis of amplitude modulation characteristics over the magnetron operating range was made with results shown as Fig. 9. To obtain these data, with the magnetron at 9.6 kMc, input video was adjusted to produce 50% modulation. The input for this condition was 60 volts peak-to-peak noise. Holding the input constant, data were taken at discrete frequencies across the rf operating band. In Fig. 9 the vertical lines indicate limits, positive and negative, of the carrier swing about its unmodulated level, which can be interpreted as modulation percentages while also exposing any lack of symmetry arising from magnetron characteristics. To further interpret amplitude-modulation characteristics, in Fig. 10 is presented a composite photograph of a cro displaying the demodulated rf output. Two displays are superimposed: to the left the video noise when the cro

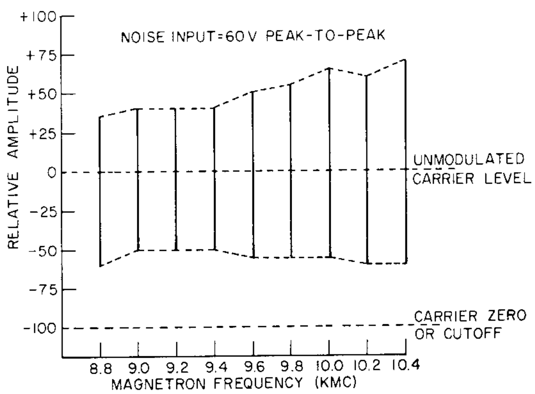


Fig. 9 - Amplitude modulation characteristics vs magnetron frequency of a modified AN/ALT-2 (X-band)

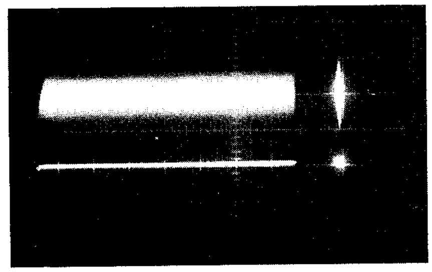
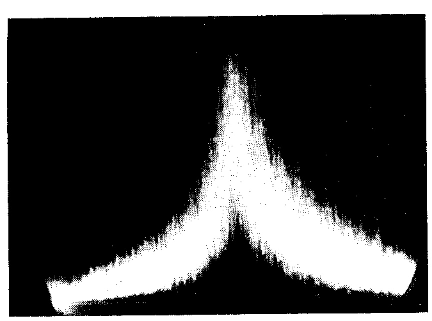


Fig. 10 - Amplitude modulation characteristics at a magnetron frequency of 9.6 kMc of a modified AN/ALT-2 (X-band)

is swept horizontally, and to the right the image when the sweep is deactivated. In each case, the lower line and dot were artificially introduced as a zero reference level. The right-hand image is the integrated excursion of the noise about an imaginary cw level and indicates substantially symmetrical peak modulation of about 50%. By comparison, the area to the left demonstrates that the recovered noise modulation has the desired random amplitude distribution with no evidence of clipping or frequency coherence. The vertical line at 9.6 kMc in Fig. 9 depicts graphically the condition shown pictorially by the right-hand image of Fig. 10.

At each data point the magnetron output was viewed on an rf spectrum analyzer with a 20-Mc display width to observe the spectral appearance under the indicated modulation variations. Since the output of a magnetron under amplitude modulation is a combination of amplitude and frequency modulation, the degree of modulation must be optimized to produce maximum sideband power without excessive frequency spreading and spectrum distortion, which latter effect can cause an apparent shift in center frequency. The output, as photographed from the spectrum analyzer at 9.6 kMc (Fig. 11) is considered to have satisfactory distribution about the center frequency with no apparent shift of maximum from the unmodulated value.

Fig. 11 - Modulated rf spectrum at 9.6 kMc (20-Mc display width) of a modified AN/ALT-2 (X-band)



Similar observations of the composite rf spectrum at other magnetron operating frequencies indicated very little deviation from that shown in Fig. 11, with the exception of the lowest frequency, 8.8 kMc, where some dissymmetry in sideband distribution was noted. The latter normally was predictable, since, as shown by Fig. 9, at that frequency the greatest measured dissymmetry in modulation swing occurred.

Figures 12 and 13 show the carrier without noise modulation but displaying the effects of hum and ripple components in the system. As seen, these produce about 1 Mc of frequency modulation, which is considered tolerable. Their effective value in amplitude modulating the carrier is somewhat less than 10% modulation as can be estimated from Fig. 13, where again the lower trace defines the 100% modulation limit.

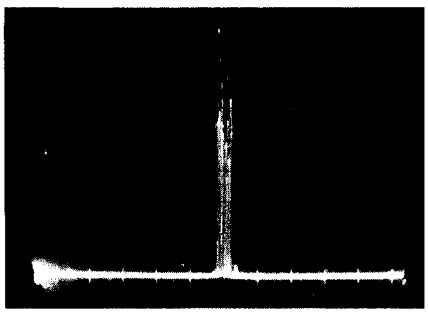


Fig. 12 - Frequency modulation due to hum in a modified AN/ALT-2 (X-band)

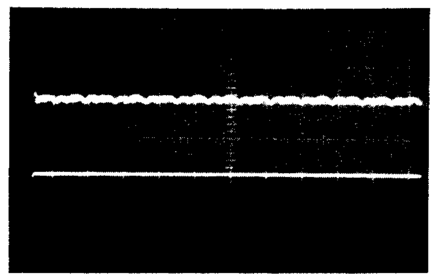


Fig. 13 - Amplitude modulation due to hum in a modified AN/ALT-2 (X-band)

These undesired modulating components have two origins: incomplete high-voltage filtering and the ac field in the vicinity of the magnetron cathode. To some extent, the effect of each can be separately evaluated from a cro display using a known time base, since the component due to the cathode will be at the fundamental ac line frequency while those arising from ineffective filtering will be at some higher harmonic frequency dependent on the type of dc rectification in the system.

CONCLUSIONS

From this investigation certain design faults in the current AN/ALT-2 have been disclosed as being responsible for the degradation in the system video response. The most glaring omission was failure to use low-capacity interwinding techniques for the filament transformer used with the magnetron discharge tube, V202, It is reasonable to assume from the pessimistic data submitted by the magnetron manufacturers relating to the excessive video drive required to produce an acceptable jamming spectrum, that this unrecognized factor seriously debased their findings. In summary, there is no evidence that the magnetron to any substantial degree restricts the reproduction of video modulation components to at least 10 Mc.

The normal variation of magnetron impedance with operating frequency reduced the video response about 1 db at the highest modulating frequency between the extremes of the rf tuning range.

With the level of amplitude modulation set to 50% at midfrequency, an acceptable rf spectrum, in terms of optimum frequency spread and symmetry, was observed across the magnetron tuning range with some slight degradation in symmetry at the minimum frequency.

RECOMMENDATION

The requirements for video components of modulation to at least 10 Mc being established as prerequisite for current noise jammers and with evidence now available that the component X-band magnetrons, used in the AN/ALT-2, are capable of reproducing these frequencies within the equipment limitations, it is recommended that the specifications be adjusted to designate this goal.

REFERENCES

1. Hollweck, F.J., "Modulation Analysis of AN/ALT-2 Jamming Transmitter," NRL Memorandum Report 952 (Confidential Report, Unclassified Title), July 15, 1959

2. Webcor, Inc., "Technical Proposal for Modifications to Countermeasures Set AN/ALQ-23" (Confidential), Jan. 8, 1960

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